XVII A.P.
DÜSSELDORF
21.5-1.6 1990
CCIR

XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990

INTERNATIONAL TELECOMMUNICATION UNION

RECOMMENDATIONS OF THE CCIR, 1990

(ALSO RESOLUTIONS AND OPINIONS)

VOLUME II

SPACE RESEARCH AND RADIOASTRONOMY SERVICES

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

CCIR

1. The International Radio Consultative Committee (CCIR) is the permanent organ of the International Telecommunication Union responsible under the International Telecommunication Convention "... to study technical and operating questions relating specifically to radiocommunications without limit of frequency range, and to issue recommendations on them..." (International Telecommunication Convention, Nairobi 1982, First Part, Chapter I, Art. 11, No. 83).*

2. The objectives of the CCIR are in particular:

a) to provide the technical bases for use by administrative radio conferences and radiocommunication services for efficient utilization of the radio-frequency spectrum and the geostationary-satellite orbit, bearing in mind the needs of the various radio services;

b) to recommend performance standards for radio systems and technical arrangements which assure their effective and compatible interworking in international telecommunications;

c) to collect, exchange, analyze and disseminate technical information resulting from studies by the CCIR, and other information available, for the development, planning and operation of radio systems, including any necessary special measures required to facilitate the use of such information in developing countries.

* *See also the Constitution of the ITU, Nice, 1989, Chapter 1, Art. 11, No. 84.*

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92-61-04171-X

Geneva, 1990

PLAN OF VOLUMES I TO XV
XVIIth PLENARY ASSEMBLY OF THE CCIR

(Düsseldorf, 1990)

VOLUME I (Recommendations) *Annex to Vol. I* (Reports)	Spectrum utilization and monitoring
VOLUME II (Recommendations) *Annex to Vol. II* (Reports)	Space research and radioastronomy services
VOLUME III (Recommendations) *Annex to Vol. III* (Reports)	Fixed service at frequencies below about 30 MHz
VOLUME IV-1 (Recommendations) *Annex to Vol. IV-1* (Reports)	Fixed-satellite service
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VOLUME V (Recommendations) *Annex to Vol. V* (Reports)	Propagation in non-ionized media
VOLUME VI (Recommendations) *Annex to Vol. VI* (Reports)	Propagation in ionized media
VOLUME VII (Recommendations) *Annex to Vol. VII* (Reports)	Standard frequencies and time signals
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Annex 1 to Vol. VIII (Reports)	Land mobile service – Amateur service – Amateur satellite service
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Annex 3 to Vol. VIII (Reports)	Mobile satelllite services (aeronautical, land, maritime, mobile and radiodetermination) – Aeronautical mobile service
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VOLUME XI-1 (Recommendations) *Annex to Vol. XI-1* (Reports)	Broadcasting service (television)
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VOLUME XV-3 (Questions)	Study Groups 10, 11, CMTT
VOLUME XV-4 (Questions)	Study Groups 4, 9

All references within the texts to CCIR Recommendations, Reports, Resolutions, Opinions, Decisions and Questions refer to the 1990 edition, unless otherwise noted; i.e., only the basic number is shown.

1990
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DISTRIBUTION OF TEXTS OF THE XVIIth PLENARY ASSEMBLY OF THE CCIR IN VOLUMES I TO XV

Volumes and Annexes I to XV, XVIIth Plenary Assembly, contain all the valid texts of the CCIR and succeed those of the XVIth Plenary Assembly, Dubrovnik, 1986.

1. Recommendations, Resolutions, Opinions are given in Volumes I-XIV and Reports, Decisions in the Annexes to Volumes I-XII.

1.1 *Numbering of texts*

When a Recommendation, Report, Resolution or Opinion is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. Within the text of Recommendations, Reports, Resolutions, Opinions and Decisions, however, reference is made only to the basic number (for example Recommendation 253). Such a reference should be interpreted as a reference to the latest version of the text, unless otherwise indicated.

The tables which follow show only the original numbering of the current texts, without any indication of successive modifications that may have occurred. For further information about this numbering scheme, please refer to Volume XIV.

1.2 *Recommendations*

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265	X/XI-3	428	VIII-2	505	XII
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268	IX-1	433	I	509, 510	II
270	IX-1	434, 435	VI	513-517	II
275, 276	IX-1	436	III	518-520	III
283	IX-1	439	VIII-2	521-524	IV-1
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305, 306	IX-1	444	IX-1	535-538	VII
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331, 332	I	460	VII	558	IV/IX-2
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341	V	467, 468	X-1	567-572	XII
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362-364	II	475, 476	VIII-2	579, 580	IV-1
367	II	478	VIII-1	581	V

1.2 *Recommendations (cont.)*

Number	Volume	Number	Volume	Number	Volume
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600	X/XI-2	645	X-1 + XII	695-701	IX-1
601	XI-1	646, 647	X-1	702-704	X-1
602	X/XI-3	648, 649	X/XI-3	705	X-1 (1)
603-606	XII	650-652	X/XI-2	706-708	X-1
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609-611	II	657	X/XI-3	712	X/XI-2
612, 613	III	658-661	XII	713-716	X/XI-3
614	IV-1	662-666	XIII	717-721	XII
615	IV/IX-2	667-669	I	722	XII
616-620	V	670-673	IV-1	723, 724	XII
622-624	VIII-1	674, 675	IV/IX-2		

1.3 *Reports*

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122	XI-1	322	VI (1)	473	X/XI-2
137	IX-1	324	I	476	XI-1
181	I	327	III	478	XI-1
183	III	336*	V	481-485	XI-1
195	III	338	V	488	XII
197	III	340	VI (1)	491	XII
203	III	342	VI	493	XII
208	IV-1	345	III	496, 497	XII
209	IV/IX-2	347	III	499	VIII-1
212	IV-1	349	III	500, 501	VIII-2
214	IV-1	354-357	III	509	VIII-3
215	X/XI-2	358	VIII-1	516	X-1
222	II	363, 364	VII	518	VII
224	II	371, 372	I	521, 522	I
226	II	375, 376	IX-1	525, 526	I
227*	V	378-380	IX-1	528	I
228, 229	V	382	IV/IX-2	533	I
238, 239	V	384	IV-1	535, 536	II
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258-260	VI	395	II	546	II
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267	VII	409	XI-1	552-558	IV-1
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279	I	439	VII	569	V
285	IX-1	443	IX-1	571	VI
287*	IX-1	445	IX-1	574, 575	VI
289*	IX-1	448, 449	IV/IX-2	576-580	VII
292	X-1	451	IV-1	584, 585	VIII-2
294	X/XI-3	453-455	IV-1	588	VIII-2
300	X-1	456	II	607	IX-1
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311-313	XI-1	463, 464	X-1	612-615	IX-1
314	XII	468, 469	X/XI-3	622	X/XI-3

* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3 *Reports (cont.)*

Number	Volume	Number	Volume	Number	Volume
624-626	XI-1	790-793	IV/IX-2	972-979	I
628, 629	XI-1	795	X-1	980-985	II
630	X/XI-3	798, 799	X-1	987, 988	II
631-634	X/XI-2	801, 802	XI-1	989-996	III
635-637	XII	803	X/XI-3	997-1004	IV-1
639	XII	804, 805	XI-1	1005, 1006	IV/IX-2
642, 643	XII	807-812	X/XI-2	1007-1010	V
646-648	XII	814	X/XI-2	1011, 1012	VI
651	I	815, 816	XII	1016, 1017	VII
654-656	I	818-823	XII	1018-1025	VIII-1
659	I	826-842	I	1026-1033	VIII-2
662-668	I	843-854	II	1035-1039	VIII-2
670, 671	I	857	III	1041-1044	VIII-2
672-674	II	859-865	III	1045	VIII-3
676-680	II	867-870	IV-1	1047-1051	VIII-3
682-685	II	872-875	IV-1	1052-1057	IX-1
687	II	876, 877	IV/IX-2	1058-1061	X-1
692-697	II	879, 880	V	1063-1072	X-1
699, 700	II	882-885	V	1073-1076	X/XI-2
701-704	III	886-895	VI	1077-1089	XI-1
706	IV-1	896-898	VII	1090-1092	XII
709	IV/IX-2	899-904	VIII-1	1094-1096	XII
710	IV-1	908	VIII-2	1097-1118	I
712, 713	IV-1	910, 911	VIII-2	1119-1126	II
714-724	V	913-915	VIII-2	1127-1133	III
725-729	VI	917-923	VIII-3	1134-1141	IV-1
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735, 736	VII	929	VIII-3 [1]	1144-1148	V
738	VII	930-932	IX-1	1149-1151	VI
739-742	VIII-1	934	IX-1	1152	VII
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748, 749	VIII-2	940-942	IX-1	1158-1168	VIII-2
751	VIII-3	943-947	X-1	1169-1186	VIII-3
760-764	VIII-3	950	X/XI-3	1187-1197	IX-1
766	VIII-3	951-955	X/XI-2	1198	X-1 [1]
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774, 775	VIII-2	958, 959	XI-1	1205-1226	XI-1
778	VIII-1	961, 962	XI-1	1227, 1228	X/XI-2
780*	IX-1	963, 964	X/XI-3	1229-1233	X/XI-3
781-789	IX-1	965-970	XII	1234-1241	XII

* Not reprinted, see Dubrovnik, 1986.

[1] Published separately.

1.3.1 *Note concerning Reports*

The individual footnote "Adopted unanimously" has been dropped from each Report. Reports in Annexes to Volumes have been adopted unanimously except in cases where reservations have been made which will appear as individual footnotes.

1.4 *Resolutions*

Number	Volume	Number	Volume	Number	Volume
4	VI	62	I	86, 87	XIV
14	VII	63	VI	88	I
15	I	64	X-1	89	XIII
20	VIII-1	71	I	95	XIV
23	XIII	72, 73	V	97-109	XIV
24	XIV	74	VI	110	I
33	XIV	76	X-1	111, 112	VI
39	XIV	78	XIII	113, 114	XIII
61	XIV	79-83	XIV		

1.5 *Opinions*

Number	Volume	Number	Volume	Number	Volume
2	I	45	VI	73	VIII-1
11	I	49	VIII-1	74	X-1 + X/XI-3
14	IX-1	50	IX-1	75	XI-1 + X/XI-3
15	X-1	51	X-1	77	XIV
16	X/XI-3	56	IV-1	79-81	XIV
22, 23	VI	59	X-1	82	VI
26-28	VII	63	XIV	83	XI-1
32	I	64	I	84	XIV
35	I	65	XIV	85	VI
38	XI-1	66	III	87, 88	XIV
40	XI-1	67-69	VI	89	IX-1
42	VIII-1	71-72	VII	90	X/XI-3
43	VIII-2				

1.6 *Decisions*

Number	Volume	Number	Volume	Number	Volume
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6	VI	64	IV-1	90, 91	XI-1
9	VI	65	VII	93	X/XI-2
11	VI	67, 68	XII	94	X-1
18	X-1 + XI-1 + XII	69	VIII-1	95	X-1 + XI-1
		70	IV-1	96, 97	X-1
27	I	71	VIII-3	98	X-1 + XII
42	XI-1	72	X-1 + XI-1	99	X-1
43	X/XI-2	76	IV-1 + X-1 + XI-1 + XII	100	I
51	X/XI-2			101	II
53, 54	I	77	XII	102	V
56	I	78, 79	X-1	103	VIII-3
57	VI	80	XI-1	105	XIV
58	XI-1	81	VIII-3	106	XI-1
59	X/XI-3	83-86	VI		

2. **Questions** (Vols. XV-1, XV-2, XV-3, XV-4)

2.1 *Numbering of texts*

Questions are numbered in a different series for each Study Group: where applicable a dash and a figure added after the number of the Question indicate successive modifications. The number of a Question is completed by an *Arabic figure indicating the relevant Study Group.* For example:

- Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;
- Question 1-1/10 would indicate a Question of Study Group 10, whose text has been once modified from the original; Question 1-2/10 would be a Question of Study Group 10, whose text has had two successive modifications.

Note – The numbers of the Questions of Study Groups 7, 9 and 12 start from 101. In the case of Study Groups 7 and 9, this was caused by the need to merge the Questions of former Study Groups 2 and 7 and Study Groups 3 and 9, respectively. In the case of Study Group 12, the renumbering was due to the requirement to transfer Questions from other Study Groups.

2.2 *Assignment of Questions*

In the plan shown on page II, the relevant Volume XV in which Questions of each Study Group can be found is indicated. A summary table of all Questions, with their titles, former and new numbers is to be found in Volume XIV.

2.3 *References to Questions*

As detailed in Resolution 109, the Plenary Assembly approved the Questions and assigned them to the Study Groups for consideration. The Plenary Assembly also decided to discontinue Study Programmes. Resolution 109 therefore identifies those Study Programmes which were approved for conversion into new Questions or for amalgamation with existing Questions. It should be noted that references to Questions and Study Programmes contained in the texts of Recommendations and Reports of Volumes I to XIII are still those which were in force during the study period 1986-1990.

Where appropriate, the Questions give references to the former Study Programmes or Questions from which they have been derived. New numbers have been given to those Questions which have been derived from Study Programmes or transferred to a different Study Group.

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VOLUME II

SPACE RESEARCH AND RADIOASTRONOMY

(Study Group 2)

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Section 2G – Radioastronomy and radar astronomy

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STUDY GROUP 2

SPACE RESEARCH AND RADIOASTRONOMY

Terms of reference:

To study questions relating to:

1. systems for the space research service, the Earth exploration-satellite service, including the meteorological-satellite service and their associated technologies, as well as general principles of systems for the operation of spacecraft;

2. systems for the radioastronomy service and for radar astronomy, with particular reference to associated interference problems.

1986-1990 *Chairman:* F. HORNER (United Kingdom)
Vice-Chairman: H. G KIMBALL (United States of America)

The Study Group 2 texts which take into account the work carried out during the 1986-1990 study period, are published for the last time in Volume II.

As from the next study period, in conformity with Resolution 61 adopted at the XVIIth Plenary Assembly, Düsseldorf (May-June 1990), questions relating to former Study Group 2, together with questions of the former Study Group 7, will be dealt with by a new Study Group (Study Group 7).

The scope of the work which will be undertaken and the names of the Chairman and Vice-Chairmen concerned are given below:

STUDY GROUP 7

SCIENCE SERVICES

Scope:

1. Systems for space operation, space research, earth exploration and meteorology, including the related use of links in the inter-satellite services;

2. radioastronomy and radar astronomy;

3. dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a world-wide basis.

1990-1994 *Chairman:* H. G. KIMBALL (United States of America)
Vice-Chairmen: J. SAINT-ETIENNE (France)
S. LESCHIUTTA (Italy)
J. WHITEOAK (Australia)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 2

1. Organization

At both the Interim Meeting in 1987 and the Final Meeting in 1989 the activity took place largely within four Working Groups, and it is appropriate to acknowledge the excellent work of the Working Group Chairmen, the Chairmen of the many sub-Groups, the Rapporteurs and all the delegates who contributed to the work. At the Interim Meeting, an ad hoc Working Group was formed to prepare material for the JIWP for WARC ORB-88. This ad hoc Group was chaired by the Study Group Vice-Chairman, Mr. H.G. Kimball, and its work was completed in a successful and timely manner. The Vice-Chairman will undertake a similar task as Chairman of IWP 2/2 in preparation for WARC-92.

The Study Group representative to CMV, Mr. N. De Groot, has played an important role in that body and on problems of terminology within the Study Group.

2. Note on the terms of reference

The present terms of reference adequately cover the range of activity undertaken except in one respect. The attention of the Study Group has been drawn to a need to make provision for systems to measure atmospheric winds by using radar equipment (wind profilers). This can be regarded as a meteorological aids service for which no Study Group clearly has responsibility in its formal terms of reference. Because Study Group 2 has expertise in meteorology, it seemed appropriate to examine whether it could be of help with this problem and a new Question has been proposed. To the extent that the observations are conducted from the ground, they are not included in the terms of reference and it is for consideration whether these should be modified to include the meteorological aids service or whether there is a more appropriate way in which the needs of this service can be studied by the CCIR. It should be noted that a new Question to CCIR from the IFRB has been addressed to three Study Groups and is identified as Question 26/2, Question 37/4 and Question 80/8. This Question involves the meteorological aids service and it would be useful for a decision to be made on where the relevant expertise may be expected to be found.

3. Documentation

The Study Group has continued to examine technical considerations pertaining to the space research, space operation, earth exploration-satellite and radio astronomy services, and an attempt has been made to present documentation for these services in well-defined, appropriate sections of the proceedings. However, to an increasing extent, space missions involve more than one of these services and the studies overlap. As one example, space operations are often integrated with other services in respect of the use of the frequency spectrum. As another example data relay satellites represent a facility available for use by several services. It is for consideration whether a more logical arrangement of texts could be devised, but until a clearly improved system is proposed, it is desirable to maintain that which has become familiar. No major change is proposed at this time.

The report following the XVIth Plenary Assembly described efforts to improve presentation of the Study Group documentation so that information which would be most relevant to an administrative radio conference or useful to other Study Groups dealing with frequency-sharing problems could be readily identified. To this end the contents of some Reports and Recommendations were rearranged to some extent and texts were classified as to whether they were concerned with general descriptions of systems and techniques, with preferred frequencies, with protection criteria, or with frequency sharing and interference. A table showing how texts were categorized has been updated to take account of new Reports and is shown in Table I of Annex I.

Table II of Annex I is an updated breakdown of texts on sharing according to competing services. Only Study Group 2 texts are tabulated but reference is made to Reports of other Study Groups dealing with sharing with Study Group 2 services. For example a proposed new Report on sharing between radio astronomy and mobile services was examined and approved by both the Study Groups concerned and it seemed appropriate for it to be a Study Group 8 Report. It can be found as Report 1182. Similarly a new proposed Report on sharing between space and terrestrial services near 2 GHz was adopted by Study Group 9, taking into account comments by Study Group 2. It has become Report 1197, which should be consulted in association with the Reports on the same subject listed in Table II.

A further comment is that Report 696, listed against radio astronomy, presents criteria relevant to all bands used for observations and involves many services. It concludes that frequency sharing is rarely feasible without large separation distances. However, sharing possibilities with some services exist if special arrangements are made to avoid interference to radio astronomy. Reports 1126 and 1182 explore such possibilities and indicate the strict control procedures which would be necessary.

4. Main changes to Volume II

Section 2A – Research in space technology

Report 676 on spacecraft charging has been substantially rewritten to improve clarity and to include recent developments.

Report 675 on reference antenna patterns has been suppressed, but some of its content has been included in a revision of the related Report 677.

Section 2B – Topics of general interest

Report 844 on interference between deep-space research and other services, owing to harmonic relationships, has been revised to take account of the use of higher deep-space frequencies. It is retained in Section 2B because the considerations are significant for other Study Group 2 services in the same or adjacent bands. However, it is for consideration whether, in further revisions of material, the space research aspects might be located in Section 2E. Report 981 on sharing with fixed services near 2 GHz has been maintained, largely unchanged, pending further discussion with Study Group 9, but, with the suppression of Report 396, one of the Annexes thereto has now been annexed to Report 981.

Reports 680 and 681 both deal with the infra-red and visible portions of the electromagnetic spectrum, as do Reports 666 and 667 of Study Group 1. As a move towards concentration of texts on this subject, Report 681 has been suppressed, with some transfer of material to Report 680. This Report should be examined further in the light of Study Group 1's actions. Study Group 2 should retain material relating to space usage of these frequencies.

The task of selecting preferred frequencies for the various services involves studies of the propagation and noise factors, for which use is made of the Reports of Study Group 5.

A new Report 1119 is an account of the sources from which the required parameters are derived and of the procedures which can be used to assess the performance of transmission links based on these parameters.

Report 700 on the search for extraterrestrial intelligence has been transferred to Section 2G as it is being kept under review by radio astronomers.

Section 2C – Space operations

Report 396, as mentioned previously, has been suppressed apart from an Annex transferred to Report 981.

Section 2D – Data relay satellites

Report 848 on characteristics of these systems has been updated to include Reports on planned new systems. Otherwise there are no changes to this Section, but it is noted that a thorough review will be needed as new systems are developed, and the problems of frequency sharing with other services need special examination.

Section 2E – Space research

Report 536 has been expanded to provide a more comprehensive account of world-wide deep-space facilities. Report 683 and Recommendation 576 on frequencies for deep space have been amended to extend the range to 40 GHz. Correspondingly Report 849 now considers frequencies from 40 GHz (rather than 20 GHz) upwards. 40 GHz is technically a more appropriate point of division. Report 685 on protection criteria for deep space has been extensively updated.

Recommendation 610 on the definition of deep space has been revised to take account of the acceptance of a new definition by the CCIR and by an administrative conference. The explanatory Report 986 has been suppressed but remains as a reference.

Section 2F – Earth exploration satellites

Report 535, with descriptions of systems, has been expanded to include new and planned systems, and Report 693 on frequency requirements has been updated and earmarked for further revision, with shortening. A similar comment applies to Report 395 on meteorological satellites.

Report 851 now includes a further discussion of the power of meteorological satellites needed for dissemination of data to earth stations, and differentiates between requirements for low-orbit and geostationary satellites.

Report 988 has been extended with a discussion of the combined use of satellites and VLBI networks for geodesy. Several new Reports have been added to this Section to assist in the understanding of problems of sharing by Earth exploration satellites. Between them they discuss methods of analysis used in coordination procedures and they study, in particular, sharing in the bands 1670-1710 MHz and 7450-7550 MHz.

Future work identified includes updating of Reports 692, 540 and 541, and Recommendation 514. Recommendation 362 could be extended to provide more specific guidance in frequency requirements for meteorological satellites.

Section 2G – Radio astronomy and radar astronomy

Report 852 has been subject to detailed changes following representations from the International Astronomical Union regarding the tables of important line frequencies. These have now been extended to 810 GHz. The Annex on the scientific interest in the lines has been suppressed but a reference is made, where appropriate, to the version in Volume II, Dubrovnik 1986.

Report 224 on protection for radio astronomy has been extended by a discussion of the response to interference when antenna arrays or interferometers, rather than single antennas are used.

Apart from updating, Recommendation 314 on protection for radio astronomy has been changed in only one respect. Attention is drawn to the necessity, on occasions, to observe spectral lines on frequencies where radio astronomy has no allocation, and administrations are encouraged to help in the coordination with other services to make such measurements practicable.

Report 696 has been changed considerably in its review of problems of interference in all bands used for radio astronomy. New material which has been introduced includes more calculations of typical separation distances for avoidance of interference, and a reference to the possibility of time-sharing in some cases. A new Annex discusses sharing of bands used for both radio astronomy and reception of signals from deep space.

Report 697 on interference to radio astronomy from spurious emissions from transmitters in other bands now examines more specific cases in which harmonic emissions could interfere. A more thorough revision of this Report is needed. Report 539 on the protection of observations on the Moon has been suppressed as a Report, but the material has been retained by annexing it to Recommendation 479 on the subject.

Report 1126 considers the problem of making radio astronomy observations on frequencies near those used for up links in the radiodetermination-satellite service. While simultaneous use of the frequencies is generally impracticable, it is feasible to make special arrangements for time sharing. The Report discusses these possibilities and examines the controls which would be needed to avoid interference to radio astronomy.

In considering future work the Study Group has noted the difficulty of making Recommendations on frequency sharing in the absence of a positive Recommendation on levels of harmful interference to radio astronomy. Recommendation 314 refers in CONSIDERING (*q*) to levels quoted in Report 224.

Discussions with the IFRB may be necessary to identify any procedural difficulties in using Report 224 tables in coordination studies.

The Study Group also noted a need to consider future revision of Report 699 on observations below 20 MHz and of Report 854 on interference from microwave ovens.

Questions and Study Programmes

As mentioned in § 2, a new Question 144/7 on radiocommunications for meteorological aids is proposed. Another proposed Question is aimed at studies of how interference to space research and radio astronomy from nominally geostationary satellites could be affected if such satellites are allowed to drift away from the equatorial plane.

No changes to other Questions are proposed but some changes to Study Programmes have been agreed, as indicated below.

Study Programme 5A-1/2 on interference to radio astronomy has been extended to include observations using antennas on earth satellites.

Study Programme 12A-2/2 has been extended by making specific reference to the need for technical parameters for use in connection with Appendices 28 and 29 of the Radio Regulations. The title of Study Programme 12B-1/2 has been modified for clarification.

Study Programme 12C/2 has had an addition corresponding to that for Study Programme 12A-2/2.

Study Programme 12E/2 has been extended with the object of studying means for establishing a network of accurately-known reference points on the solid surface of the Earth for geodetic applications.

General comments

The Study Group has attempted to minimize the increase in size of Volume II but has found it necessary to add eight new Reports, with less-extensive deletions. Strong efforts to delete old material will need to be made in the next cycle to avoid further expansion.

The CCIR is encouraged to produce more Recommendations, if necessary at the expense of Reports. Such a policy needs to be based on adequate preparation, and administrations are encouraged to provide appropriate contributions to Study Group 2 for its next Interim Meeting.

5. Terminology

Following CCIR agreement on the definition of deep space, no problems have been referred to CMV for general consideration. However, there are two matters on which the Study Group has not yet achieved consistency within its own documentation, and which should be given more attention.

The Study Group has many well-established texts referring to "protection criteria" for its services. Some of the new texts now agreed include the terms "interference criteria" and "sharing criteria" and it is desirable that their meanings should be clearly understood. A study of the contexts suggests that "interference criteria" and "protection criteria" are essentially the same and refer to the maximum interference which can be received by a service without being harmful. The criteria may include both magnitude and time-duration factors.

Interference may often arise from a combination of several sources and, in studies of frequency sharing, it may be necessary to specify guidelines for a single one of the sources, taking into account both an assumed number which coexist, and the interference or protection criteria which are to be met. The term "sharing criteria" appears to relate to the guidelines for each source of interference.

These terms should be examined to ensure that they are clear and used consistently, noting that there is some usage by other Study Groups. The review could also include the term "performance criteria", although this appears to pose fewer problems.

A second problem relates to the use of the term "spreading loss" which is not used consistently in the Reports of the Study Group. Expressed in dB it is sometimes defined as a positive value and sometimes negative, and even within one Report the signs of the values quoted are not consistent with the definition. Such variations tend to confuse the reader and could be removed in further revisions of the Reports. As a negative loss is a gain, it seems logical that all losses should be positive numbers when expressed in dB, and should be defined correspondingly. Reports 536, 540, 694, 844 and 982 do not follow this convention.

6. Preparations for WARC-92

The WARC which has been planned for 1992, to consider services in the approximate range 1-3 GHz and above 20 GHz, could make decisions having a profound influence on the services of Study Group 2. It is important, therefore, that the technical preparations for the Conference should be carried out thoroughly and as rapidly as possible. The Study Group agreed Decision No. 101 setting up IWP 2/2 to carry out this work. If a proposed JIWP of several Study Groups is set up to report to the WARC, the findings of IWP 2/2 will be made available to that JIWP, and will also be submitted to the Interim Meeting of the Study Group. Working Groups of the Study Group have identified texts from the Final Meeting which are relevant to WARC-92 and which should be examined by the IWP.

7. Relations with other Study Groups

Study Group 1

The mutual interests of the two Study Groups include frequency sharing, and the revised tables of texts in Annex I are drawn to the attention of Study Group 1. Another area of overlap is the study of communications using the infra-red and visible portions of the spectrum. Study Group 2 has revised Report 680, incorporating essential elements of Report 681 (otherwise suppressed) which relate to its own services, leaving Study Group 1 to deal with more general issues, if it so desires, when it considers its Reports 666 and 667.

The interest of Study Group 2 in the control of spurious emissions remains high but there is little to add to the comments made in 1986, which remain largely valid. Report 980 has been maintained without change but should be re-examined when the related Reports of Study Group 1 have been studied.

Study Group 4

Study Group 2 received two contributions concerning physical interference between satellites, and noted that they had been submitted also to Study Group 4, which had the primary interest. Comments were offered for consideration by Study Group 4.

Two other documents relating to possible interference between fixed satellites and low-orbit meteorological satellites in the band 7450-7550 MHz were also examined by both Groups. Although it was noted that under RR 2613, no interference to fixed satellites is allowed, the Reports are useful to Study Group 2 in providing guidance on what action, if any, might be taken to comply with RR 2613 and Study Group 4 might wish to note the arguments on which decisions of the meteorological-satellite service would be based. The Reports are 1124 and 1125.

Study Group 2 discussed a Study Group 4 proposal on the possible formation of a joint IWP concerned with Appendix 28 of the Radio Regulations. The Study Group expressed an interest in participating and has noted that Study Group 4, with Study Group 9, has taken this interest into account in drafting Decision 87.

Note has been taken of a new Study Programme 33C/4 dealing with frequency sharing which might involve Study Group 2 services. Further developments in this area will be examined with interest for comparison with corresponding work in Study Group 2.

Study Group 9

The most important aspects of relationships with Study Group 9 relate to the problems of sharing between space and radio-relay services, especially at frequencies near 2 GHz. A suggestion of a joint IWP was not endorsed by Study Group 2, which considered that the objectives could be pursued by less formal arrangements. It has nominated Mr. J.N. Scott as a coordinator and has noted that Mr. G. Hurt will coordinate on behalf of Study Group 9. Two input documents (9/314 and 9/315) on this subject were submitted to Study Group 9 and were also examined by Study Group 2, whose comments were taken into account in drafting Report 1197. It is noted that this Report gives both 1982 and 1986 versions of Report 684 as references so some rationalization of this Report may be useful.

ANNEX I

TABLE I – *Classification of some Reports and Recommendations of Study Group 2*

Service or activity	Characteristics	Preferred frequencies	Protection criteria	Sharing and interference
Space operations	Rep. 845	Rec. 363	Rec. 363	Rep. 678 Rep. 981 Note 1
Data relay satellites	Rep. 848 Rep. 982			Rec. 510 Rep. 983 Rep. 846 Rep. 847 Rep. 981
Near-Earth space research	Rep. 548 Rep. 456 Rep. 684	Rec. 364 Rec. 513 Rep. 984	Rec. 364 Rec. 609 Rep. 985	Rep. 687 Rep. 981 Note 1
Deep-space reseach	Rec. 610 Rep. 536 Rep. 986	Rec. 576 Rep. 683 Rep. 849	Rec. 578 Rep. 685	Rec. 578 Rep. 685 Rep. 844
Earth exploration satellites (general)	Rep. 535 Rep. 538 Rep. 988	Rec. 514 Rep. 692	Rep. 1123	Rep. 540 Rep. 981 Rep. 1122
Meteorological satellites	Rep. 395	Rec. 362	Rep. 1124 Rep. 1121	Rep. 541 Rep. 851 Rep. 1121 Rep. 1124 Rep. 1125
Earth exploration satellites (sensors)		Rec. 515 Rec. 577 Rep. 693		Rec. 516 Rep. 694 Rep. 850 Rep. 987 Rep. 695
Radio and radar astronomy	Rep. 852 Rep. 699 Rep. 226		Rec. 314 Rec. 479 Rep. 224	Rec. 517 Rec. 611 Rep. 696 Rep. 697 Rep. 853 Rep. 854 Rep. 844 Rep. 1126 Note 2 Note 3

Note 1 – See also Report 1197.

Note 2 – See also Report 1182.

Note 3 – See also Report 631 in Volume X/XI-2.

TABLE II – *Study Group 2 texts on frequency sharing*

Study Group 2 service or activity	General	Fixed and mobile	Fixed satellite	Broadcasting and broadcasting satellite	Radiodetermination satellite	Radiolocation	Aeronautical radionavigation	Mobile satellite	Aeronautical mobile	Intersatellite
Space operations		Rep. 981 Note 1								
Data relay satellites		Rec. 510 Rep. 847 Rep. 981 Rep. 982	Rep. 847 Rep. 982			Rep. 847				
Near-Earth space research	Rep. 456 Rep. 548	Rep. 687 Rep. 984 Note 1								
Deep-space research	Rec. 578 Rep. 685		Note 2	Note 2						
Earth exploration satellites (general)	Rep. 1122	Rep. 540 Rep. 981 Rep. 982	Rep. 540 Rep. 982							
Meteorological satellites	Rep. 1121 Rep. 1124		Rep. 694 Rep. 850 Rep. 1125				Rep. 694			Rep. 694
Earth exploration satellites (sensors)		Rep. 694 Rep. 850	Rep. 694 Rep. 850	Rep. 694		Rec. 516 Rep. 694 Rep. 695	Rep. 694	Rep. 694		Rep. 694
Radioastronomy	Rep. 696	Rep. 696	Rep. 696	Rep. 696 Note 3	Rep. 696 Rep. 1126	Rep. 696	Rep. 696	Rep. 696 Note 4	Rep. 696	Rep. 696

Note 1 – See also Reports 1197 and 1126.

Note 2 – Report 844 should also be noted, although not strictly a sharing Report it considers mutual interference between these systems due to harmonic emissions.

Note 3 – See also Report 631 in Volume X/XI-2.

Note 4 – See also Report 1182.

SECTION 2A: RESEARCH IN SPACE TECHNOLOGY

RECOMMENDATION 509-1

GENERALIZED SPACE RESEARCH EARTH STATION ANTENNA RADIATION PATTERN FOR USE IN INTERFERENCE CALCULATIONS, INCLUDING COORDINATION PROCEDURES

(Question 15/2 and Study Programme 15A/2)

(1978-1990)

The CCIR,

CONSIDERING

(a) that the application of coordination procedures between space research earth stations and stations of other services is dependent upon specific antenna radiation patterns;

(b) that where this information does not exist, it may be desirable to use a reference antenna radiation pattern which represents the side-lobe gain levels that are not expected to be exceeded at most off-axis angles in the majority of antennas used in the service;

(c) that measured data from some large ($D/\lambda \geqslant 100$) parabolic Cassegrain antennas used in the Space Research Service indicate an off-axis discrimination that is as good as, or better than, that of the reference radiation pattern presented in Report 677,

UNANIMOUSLY RECOMMENDS

1. that in the absence of measured data on the levels of side-lobe response of a space research earth-station antenna which is subject to interference analyses or coordination procedures, the following reference radiation pattern be used to represent provisionally the space research earth station side-lobe response;

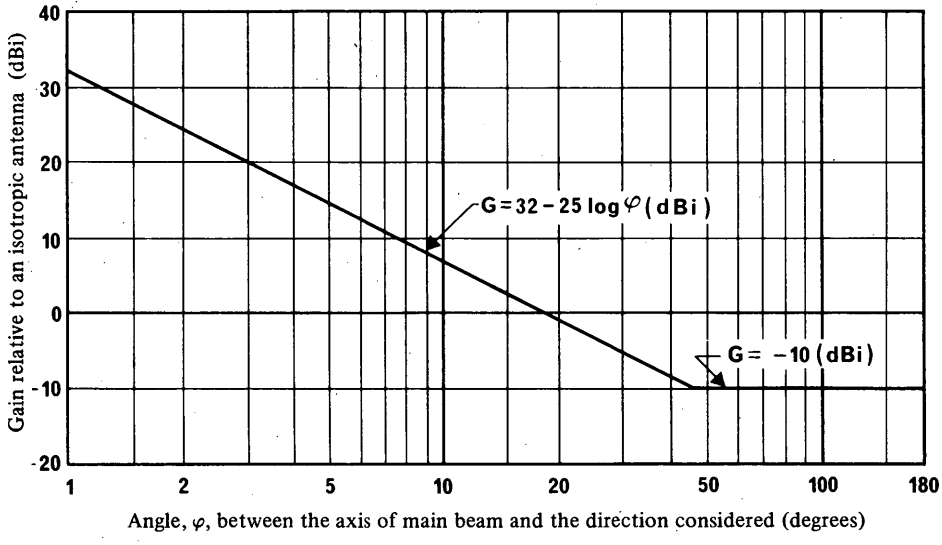

FIGURE 1 – *Reference radiation diagram to be used in the absence of measured data*

2. that this reference radiation pattern be used only for antennas the diameters of which are greater than 100 wavelengths, for angles greater than 1° from the main beam axis and for frequencies between 2 GHz and about 30 GHz;

3. that administrations be invited to submit measured antenna radiation patterns which may be used to improve the accuracy of the provisional reference radiation diagram in Fig. 1.

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SECTION 2B: TOPICS OF GENERAL INTEREST

RECOMMENDATION 367

FREQUENCY BANDS FOR RE-ENTRY COMMUNICATIONS

(Question 3/2)

(1963)

The CCIR,

CONSIDERING,

(a) that spacecraft re-entering the Earth's atmosphere are enveloped in a self-induced plasma;

(b) that electromagnetic radiations to and from the vehicle may suffer severe attenuation and other detrimental effects due to the existence of the plasma;

(c) that communications with, and tracking of, the vehicle may be imperative during the re-entry phase to ensure a successful mission;

(d) that the selection of frequency bands for re-entry communications and tracking is dictated partly by the parameters of the induced plasma;

(e) that the use of such bands requires international agreement, since the phases of re-entry flight may extend over one or more orbits of the Earth;

(f) that the only proved solution to the re-entry communication problem to date involves the use of frequencies greater than the critical frequency of the plasma sheath;

(g) that critical frequencies of the plasma sheath can approach or exceed 10 GHz;

(h) that frequencies of 10 GHz and higher are affected appreciably by the Earth's atmosphere;

(j) that the bands available at present for space research purposes above 15 GHz are technically suitable for some re-entry communications,

UNANIMOUSLY RECOMMENDS

that both the critical frequency of the plasma sheath and the atmospheric effects be considered in the selection of frequencies for re-entry communications (see Reports 205 and 222).

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SECTION 2C: SPACE OPERATIONS

RECOMMENDATION 363-4*

SPACE OPERATION SYSTEMS

Frequencies, bandwidths and protection criteria

(Question 18/2)

(1963-1974-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that the frequencies technically suitable for maintenance telemetering, tracking and telecommand of developmental and operational radionavigation, meteorological, communication, earth exploration and broadcasting satellites lie in the range from 100 MHz to 30 GHz;

(b) that the preferred bands of frequencies for maintenance telemetering, precision tracking and telecommand are between 1 and 8 GHz;

(c) that, as an exception, bands of frequencies above about 10 GHz are technically suitable for use for maintenance telemetering, tracking and telecommand during the re-entry of satellites into the atmosphere of the Earth (see Report 222);

(d) that the integration of maintenance telemetering, tracking and telecommand links with data transmission and communication systems may have advantages which include, among others, efficient use of the spectrum particularly for the on-station operational phase of geostationary satellites;

(e) that the validity of this approach has been demonstrated in some operational systems;

(f) that satellite safety nonetheless requires wide-coverage antenna radiation to maintain links during specific phases of launch and orbit transfer or in cases of momentary loss of attitude, and that wide-coverage radiation is difficult to obtain at frequencies above 8 GHz;

(g) that, in the case of broadcasting satellites, the World Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service, Geneva, 1977 (WARC-BS-77) planned the use of the bands 11.7 to 12.5 GHz in Region 1 and 11.7 to 12.2 GHz in Region 3 by allotting channels to the administrations in those Regions for satellite broadcasting, that no specific allotments were made for maintenance telemetering, tracking and telecommand (although the WARC-BS-77 reserved guardbands at the edges of both bands) and that consequently it may be difficult to use these bands also for maintenance telemetering, tracking or telecommand. (Some potential difficulties involved in this particular implementation of the space operation function are discussed in Report 1076.) The Regional Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service in Region 2 (RARC SAT-83) specified that space operation systems could be used in the allotted guardbands of 12 MHz at each end of the 12.2 to 12.7 GHz and 17.3 to 17.8 GHz bands for Region 2;

(h) that, in most cases, the necessary bandwidths for space operations are determined by the transmission of ranging signals, and usually lie between 200 kHz and 1 MHz with classical modulation methods;

(j) that the e.i.r.p. of space station transmitters is limited, so that earth receiving stations must operate at maximum sensitivity;

(k) that the e.i.r.p. of earth-station transmitters can be increased within the limits defined in the Radio Regulations to give an acceptable protection ratio at space station receiver inputs,

UNANIMOUSLY RECOMMENDS

1. that bands of frequencies below 1 GHz are technically suitable for use for some types of maintenance telemetering, tracking and telecommand of developmental and operational low-orbit (for example, below 2000 km) satellites;

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* This Recommendation should be brought to the attention of Study Groups 4, 8, 9, 10 and 11.

2. that frequencies for maintenance telemetering, precision tracking and telecommand should be between 1 and 8 GHz;

3. that as an exception, bands of frequencies above about 10 GHz be used for maintenance telemetering, tracking and telecommand during the re-entry of satellites into the atmosphere of the Earth (see Report 222);

4. that, for satellite systems such as those used for meteorological, radionavigation, communication, earth exploration and broadcasting purposes, and taking account of requirements for reliability and economical use of the frequency spectrum and for the safety of spacecraft in all phases of operation, frequencies within the mission bands used for data transmission or communications are preferred for use for maintenance telemetering, tracking and telecommand, where practicable. Where this is not practicable, frequencies in the bands specifically allocated to the space operation service should be used;

5. that the special needs for maintenance telemetering, tracking and telecommand be considered in the planning of frequencies for the broadcasting-satellite service and for the associated feeder links;

6. that the protection criteria for earth-station receivers be as follows: for frequencies above 1 GHz, total interference power in each band 1 kHz wide must not exceed -184 dBW at the receiver input for more than 1% of the time each day; for frequencies below 1 GHz, this value is increased by 20 dB per decreasing frequency decade;

7. that the protection criteria for spacecraft receivers be as follows: the ratio of signal power to total interference power in each band 1 kHz wide must not fall below 20 dB for more than 1% of the time, each day;

8. that, as these criteria are insufficient to guarantee the safety of spacecraft in certain brief critical phases, such as launching, the administrations concerned should coordinate to guarantee the safety of spacecraft during such brief critical phases.

SECTION 2D: DATA RELAY SATELLITES

RECOMMENDATION 510-1 *

FEASIBILITY OF FREQUENCY SHARING BETWEEN THE SPACE RESEARCH SERVICE AND OTHER SERVICES IN BAND 10

Potential interference from data relay satellite systems

(Question 11/2)

(1978-1982)

The CCIR,

CONSIDERING

(a) that Report 847 refers to the feasibility of frequency sharing within the range 13 to 16 GHz between near-Earth space research applications (transmitters of the data relay satellite system) and other services, namely the fixed and mobile services and radiolocation service;

(b) that, following the provisions of the WARC-79, the space research service may operate on a secondary basis in some of the bands where the above services are primary;

(c) that Report 847 indicates that the data relay satellite transmitters can meet the power flux-density limits given in Recommendation 358 and adopted by the WARC-79 for sharing between the fixed-satellite service and the fixed and mobile services,

UNANIMOUSLY RECOMMENDS

1. that frequency sharing, on a non-interference basis, between transmitters in the space research service and receivers of the fixed and mobile services or the radiolocation service is feasible near 14 and 15 GHz provided that appropriate power flux-density limits are specified for the space research service;

2. that, in frequency bands near 14 and 15 GHz shared between the space research service (data relay satellite systems), and the fixed and mobile services or the radiolocation service, the space research satellites can operate with the following power flux-density limits produced at the surface of the Earth in any 4 kHz band for all conditions and methods of modulation not exceeding:

-148	$dB(W/m^2)$	for	$0° < \delta \leqslant 5°$
$-148 + (\delta - 5)/2$	$dB(W/m^2)$	for	$5° < \delta \leqslant 25°$
-138	$dB(W/m^2)$	for	$25° < \delta \leqslant 90°$

where δ is the angle of arrival of the radio-frequency wave (degrees above the horizontal);

and that these limits relate to the power flux-density and angles of arrival which would be obtained under free-space propagation conditions.

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* This Recommendation should be brought to the attention of Study Groups 8 and 9.

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SECTION 2E: SPACE RESEARCH

RECOMMENDATION 576-1

PREFERRED FREQUENCIES AND BANDWIDTHS FOR DEEP-SPACE RESEARCH

(Question 22/2, Study Programme 22A/2)

(1982-1990)

The CCIR,

CONSIDERING

(a) that frequencies most suited for telecommunications between the Earth and spacecraft in deep space are determined partly by atmospheric and interplanetary propagation phenomena;

(b) that technology also influences the selection of preferred frequencies;

(c) that requirements for telecommunication reliability must be satisfied during periods of adverse atmospheric effects;

(d) that the same frequency may be used for spacecraft at different celestial coordinates, but that different spacecraft in the vicinity of the same coordinates and within the beamwidth of an earth station antenna will usually require different frequencies;

(e) that it is practical and desirable to effect telemetering and tracking functions on the same space-to-Earth link, and telecommand and tracking functions on the same Earth-to-space link;

(f) that to effect precision tracking, a pair of coherently-related Earth-to-space and space-to-Earth frequencies is desirable;

(g) that for more accurate calibration of the effects of charged particles on the velocity of propagation, simultaneous use of links with coherent frequencies in two or more widely separated bands is required;

(h) that voice and video links associated with manned spacecraft in deep-space could use frequency bands allocated for telemetering, telecommand and tracking functions;

(j) that Report 683 considers the selection of preferred frequencies for deep-space research in the 1 to 40 GHz range;

(k) that Report 849 considers the selection of preferred frequencies for deep-space research in the 40 to 120 GHz range,

UNANIMOUSLY RECOMMENDS

1. that frequency bands for deep-space research in the 1 to 40 GHz range be located, with due regard to the feasibility of sharing, in the preferred frequency ranges listed in Table I of Report 683, taking into account the bandwidth requirements and equipment characteristics described in Reports 536 and 683;

2. that frequency bands for deep-space research in the 40 to 120 GHz range be located, with due regard to the feasibility of sharing, in the preferred frequency ranges listed in Table I of Report 849, taking into account the bandwidth requirements and equipment characteristics described in Reports 536 and 849.

RECOMMENDATION 364-4*

PREFERRED FREQUENCIES AND BANDWIDTHS FOR MANNED AND UNMANNED NEAR-EARTH RESEARCH SATELLITES

(Question 22/2 and Study Programme 22B/2)

(1963-1966-1970-1978-1986)

The CCIR,

CONSIDERING

(a) that suitable operating frequencies and required radio-frequency bandwidths for near-Earth space research missions are determined by propagation factors and technical considerations given in Report 984;

(b) that two-way communication is required for many near-Earth missions, and is vital for manned missions;

(c) that requirements for telecommunication reliability must be satisfied during periods of adverse atmospheric conditions;

(d) that it is practical and desirable to effect telecommunication functions on a single link;

(e) that to effect precision tracking, a pair of coherently related Earth-to-space and space-to-Earth frequencies is desirable;

(f) that for simultaneous transmit/receive operations involving a single antenna, the paired Earth-to-space and space-to-Earth frequencies should be separated by at least 7%;

(g) that space-to-space and Earth/space relay satellite telecommunications are necessary to accommodate the growth and development of near-Earth investigations in the space research service;

(h) that particular modulation and channel coding techniques may be required for some links in order to comply with power flux-density limits or to guard against multipath and/or interference effects,

UNANIMOUSLY RECOMMENDS

1. that frequency bands for near-Earth missions in the space research service be located, with due regard to the purpose of the link and to the feasibility of sharing, in the preferred frequency ranges listed in Table II of Report 984;

2. that the widths of the allocated bands at preferred frequencies satisfy the individual link bandwidth requirements listed in Table III of Report 984 in order to provide for present and future near-Earth telecommunications in multi-spacecraft, multi-mission systems, within the space research service.

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* This Recommendation should be brought to the attention of Study Groups 1, 4, 7, 8, 9, 10 and 11.

RECOMMENDATION 609*

PROTECTION CRITERIA FOR TELECOMMUNICATION LINKS FOR MANNED AND UNMANNED NEAR-EARTH RESEARCH SATELLITES**

(Study Programme 1C/2)

(1986)

The CCIR,

CONSIDERING

(a) that limiting interference criteria for telecommunication links for near-Earth space research are determined by the technical considerations examined in Report 985;

(b) that, based on past experience, it is expected that up to 100 or more active near-Earth space research spacecraft may be in orbit simultaneously;

(c) that there is an increasing use of near-Earth space by both manned and unmanned space research missions;

(d) that two-way communication is required for many near-Earth missions, and is vital for manned missions;

(e) that typical operating noise temperatures of earth stations can be as low as 70 K (equivalent to −210 dB(W/Hz)) in the 1-10 GHz frequency range;

(f) that typical operating noise temperatures of space stations are near 600 K (equivalent to −171 dB(W/kHz)) in the frequency range below about 10 GHz;

(g) that link margins for typical space-to-Earth or space-to-space links are small, typically between 3 and 6 dB;

(h) that a 1 dB increase in overall system noise due to interference is considered harmful;

(j) that a noise to interference ratio of about 6 dB results in a 1 dB increase in overall system operating temperatures;

(k) that technical and/or regulatory limitations may restrict increases in spacecraft power as a means of minimizing interference;

(l) that difficulties can be expected when frequencies are shared between near-Earth spacecraft in the space research service and stations in other services,

UNANIMOUSLY RECOMMENDS

1. that protection criteria for earth stations in the space research service be established as follows:

1.1 −216 dB(W/Hz) at the input terminals of the receiver, for bands in the 1-20 GHz frequency range. For frequencies below 1 GHz, the protection criterion may be increased at the rate of 20 dB per decreasing frequency decade;

1.2 calculation of interference that may result from atmospheric and precipitation effects should be based on weather statistics for 0.001% of the time for manned missions and for 0.1% of the time for unmanned missions;

2. that protection criterion for space research space stations in low orbit be established as follows: −177 dB(W/kHz) at the input terminals of the receiver, for 0.1% of the time for both manned and unmanned spacecraft, for bands in the 100 MHz-30 GHz frequency range;

3. that frequency sharing be accomplished to the maximum extent feasible among near-Earth spacecraft in the space research service;

4. that note be taken of the difficulties to be expected in frequency sharing between near-Earth spacecraft in the space research service and stations in other services;

5. that note be taken of the difficulties to be expected in frequency sharing between near-Earth and deep-space stations in the space research service.

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* This Recommendation should be brought to the attention of Study Groups 1, 4, 8, 9, 10 and 11.

** Protection criteria for space research (deep space) can be found in Recommendation 578.

RECOMMENDATION 578*

PROTECTION CRITERIA AND SHARING CONSIDERATIONS RELATING TO DEEP-SPACE RESEARCH**

(Question 1/2)

(1982)

The CCIR,

CONSIDERING

(a) that manned deep-space research has unique requirements for extreme reliability of telecommunications so as to ensure safety of life;

(b) that both manned and unmanned deep-space research have unique requirements for extreme reliability of telecommunications so as to ensure successful reception of valuable scientific data collected at particular critical times, and that repeat transmission of these data is often not possible;

(c) that the extreme sensitivity of deep-space earth stations results in unusually low levels of permissible interference;

(d) that some terrestrial and earth stations in other services have sufficient e.i.r.p. to cause interference to stations in deep space;

(e) that sharing studies and protection criteria have been presented in Report 685 for deep-space research earth stations and for stations in deep space;

(f) that protection criteria for relay stations in earth orbit, used for deep-space research, have not yet been determined and are not considered in Report 685,

UNANIMOUSLY RECOMMENDS

1. that protection criteria for deep-space research earth stations be established as follows: -222 dB(W/Hz) in the bands near 2 GHz, -220 dB(W/Hz) in the bands near 8 GHz, -220 dB(W/Hz) in the bands near 13 GHz and -216 dB(W/Hz) in the bands near 32 GHz;

2. that protection criteria for stations in deep space be established as follows: -191 dB(W/20 Hz) in the bands near 2 GHz, -189 dB(W/20 Hz) in the bands near 7 GHz, -186 dB(W/20 Hz) in the bands near 17 GHz and -184 dB(W/20 Hz) in the bands near 34 GHz;

3. that calculation of interference that may result from atmospheric and precipitation effects be based on weather statistics for 0.001% of the time;

4. that with coordination, deep-space research can share Earth-to-space bands with stations in other services except:

- receiving aeronautical mobile stations, receiving satellite stations, and microwave sensor satellites, when any of these may come within line-of-sight;
- receiving mobile stations that come within the separation distance required for interference protection;
- transmitting terrestrial stations having an average e.i.r.p. exceeding 81 dBW in the bands near 2 GHz and 84 dBW in the bands near 7 GHz;

5. that with coordination, deep-space research can share space-to-Earth bands with stations in other services except:

- the radioastronomy service;
- transmitting aeronautical mobile stations, transmitting satellite stations, and active microwave sensor satellites, when any of these may come within line-of-sight;
- transmitting mobile stations that come within the separation distance required for interference protection.

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* This Recommendation is brought to the attention of Study Groups 4, 8, 9, 10 and 11.

** Protection criteria for near-Earth space research satellites can be found in Recommendation 609.

RECOMMENDATION 513-1

PREFERRED FREQUENCY BANDS FOR SPACECRAFT TRANSMITTERS USED AS BEACONS

(Question 10/2)

(1978-1986)

The CCIR,

CONSIDERING

(a) that a continuing need is envisaged for space experiments for research of the neutral and ionized atmosphere;

(b) that the conclusions drawn in Report 456 indicate the necessity for certain frequencies in order to contribute to these studies and measurements;

(c) that to measure differential Doppler effect, use should be made of two harmonically related frequencies;

(d) that simple techniques to measure Faraday rotation effects need two VHF frequencies differing by 1 to 3%;

(e) that based on frequency dependence of the atmospheric attenuation, frequencies near 15, 20, 30, 90 and 150 GHz are technically suitable for measurement of the neutral atmosphere;

(f) that sharing of beacon frequencies in the space research service with other services has introduced serious difficulties through interference,

UNANIMOUSLY RECOMMENDS

1. that in addition to frequencies presently allocated, a frequency harmonically related to 20 MHz and located in the range 80 to 200 MHz is technically suitable and desirable for differential Doppler observations;

2. that consideration be given to improved protection of the 40.98 to 41.015 MHz band allocated for Faraday rotation measurements;

3. that frequencies near 15, 20, 30, 90 and 150 GHz are desirable for measurements of the neutral atmosphere.

RECOMMENDATION 610-1 *

PROTECTION OF ALLOCATIONS FOR DEEP-SPACE RESEARCH **

(Question 14/2)

(1986-1990)

The CCIR,

CONSIDERING

(a) that difficulties can arise if spacecraft in the neighbourhood of the Moon, in highly elliptic Earth orbits, or in halo orbits around the L_1 or L_2 Sun-Earth Lagrangian points, share frequencies with spacecraft engaged on missions to much greater distances, e.g. to the planets;

(b) that the regulatory definition of deep-space (RR 169) was revised by WARC ORB-88 to become effective in March 1990;

Deep Space: space at distances from the Earth equal to or greater than 2×10^6 km;

(c) that the maximum distance from Earth to spacecraft in L_1 or L_2 halo orbits or in highly elliptic earth orbits, is less than 2×10^6 km;

(d) that spacecraft in these orbits or in the neighbourhood of the Moon can more readily share frequencies with spacecraft on missions nearer the Earth,

UNANIMOUSLY RECOMMENDS

that, where possible under the current Radio Regulations, the use of frequencies specifically allocated for deep-space missions be avoided for spacecraft which remain within 2×10^6 km of the Earth.

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* This Recommendation should be brought to the attention of Study Group 4 and the CMV.

** Technical background for this Recommendation may be found in Report 986 (Dubrovnik, 1986).

SECTION 2F: EARTH EXPLORATION SATELLITES

RECOMMENDATION 514-1

TELECOMMUNICATION LINKS FOR EARTH EXPLORATION SATELLITES

Frequencies, bandwidths and criteria for protection from interference

(Question 12/2)

(1978-1990)

The CCIR,

CONSIDERING

(a) that suitable operating frequencies, required radio frequency bandwidths, and limiting interference criteria for Earth exploration satellite telecommunication links are determined by the technical considerations set forth in Reports 540 and 692;

(b) that two-way communication is required for Earth exploration satellite missions;

(c) that precision tracking is required for many Earth exploration satellite missions;

(d) that bandwidths up to 100 MHz are required by currently planned Earth exploration satellites for transmission of wideband data both direct to earth stations as well as via data relay satellites;

(e) that future bandwidth requirements may be as high as 800 MHz for data readout from a single spaceborne sensor;

(f) that bandwidths of the order of 50 MHz are required for transmission of wideband data to low-cost earth stations;

(g) that transmission of wideband data to low cost earth stations results in high power flux densities;

(h) that for many Earth exploration missions the typical noise temperature of earth station receivers at frequencies above 1 GHz will be of the order of 100 K, equivalent to -148 dB(W/MHz) and that for reception at frequencies less than 1 GHz cosmic noise increases the system noise temperature approximately as the inverse of the square of the frequency;

(j) that typical operating noise temperatures for receivers in Earth exploration spacecraft are approximately 600 K (-171 dB(W/kHz)), but that measures can be taken to protect the spacecraft receiving system against interference approximately 10 dB greater than this noise level;

(k) that for some frequency sharing situations between Earth exploration satellites and certain representative terrestrial services, separations of several hundreds of kilometers between the Earth terminals may be required and that, in many parts of the world, separations of this magnitude are not readily attainable;

(l) that frequency sharing among Earth exploration satellites is desirable and feasible;

(m) that difficulties can be expected when frequencies are shared between Earth exploration satellites and stations in other services, due to the technical problems of furnishing the required protection against interference from terrestrial services,

UNANIMOUSLY RECOMMENDS

1. that frequencies for Earth exploration satellite telecommunication links be located in the frequency band between 100 MHz and 30 GHz;

2. that the band between 1 GHz and 20 GHz be used for telemetering, precision tracking and telecommand utilizing direct transmission to and from earth stations;

3. that the band between 1 GHz and 30 GHz be used for telemetering, precision tracking and telecommand via data relay satellites;

4. that the special needs for high power flux-densities for wideband data transmissions to low-cost earth stations should be considered in selection of frequencies for Earth exploration satellites;

5. that spectrum bandwidth of the order of 50 MHz per link (due account being taken of the dependence of the radio-frequency bandwidths on the type of modulation used) be available for the transmission of wideband information to low-cost earth stations;

6. that spectrum bandwidth of the order of 200 to 800 MHz per link be available for transmission of wideband information direct to major data acquisition facilities and to data relay satellites;

7. that note be taken of the difficulties to be expected in frequency sharing between Earth exploration satellites telecommunication links and passive microwave sensors operating on the same spacecraft, for example, in frequency bands such as that around the water vapour line at 22.235 GHz;

8. that frequency sharing be accomplished to the maximum extent feasible among earth exploration satellites;

9. that the protection criteria for Earth receiving sites be established as follows: for frequencies between 1 and 10 GHz, the power spectral density of noise-like interference or the total power of CW-type interference in any single band or in all sets of bands shall not exceed -154 dB(W/MHz) at the receiver input for more than 1% of the time; for frequencies less than 1 GHz, the permissible interference may increase at the rate of 20 dB per decreasing frequency decade;

10. that the protection criteria for near-Earth spacecraft receivers be established as follows: for frequencies between 300 MHz and 10 GHz, the power spectral density of noise-like interference or the total power of CW-type interference in any single band or in all sets of bands 1 kHz wide shall not exceed -161 dB(W/kHz) at the receiver input for more than 0.1% of the time; for frequencies less than 300 MHz, the permissible interference may increase at the rate of 20 dB per decreasing frequency decade;

11. that note be taken of the difficulties to be expected in frequency sharing between Earth exploration satellites and stations in other services.

RECOMMENDATION 515-1

FREQUENCY BANDS AND PERFORMANCE REQUIREMENTS FOR SATELLITE PASSIVE SENSING

(Question 12-2/2 and Study Programme 12B-1/2)

(1978-1990)

The CCIR,

CONSIDERING

(a) that passive microwave sensor technology is being applied to remote sensing by Earth exploration and meteorological-satellites in certain frequency bands allocated for such use in the Radio Regulations;

(b) that some of these bands are also allocated to other radio services;

(c) that protection from interference on certain frequencies is essential to the advancement of passive sensing measurements and applications;

(d) that for measurements of known spectral lines, certain bands at specific frequencies are of particular importance;

(e) that, for other types of passive sensor measurements, a certain number of frequency bands are in use, the exact positions of which in the spectrum are not of critical importance so long as the centre frequencies are more or less uniformly distributed in the spectrum;

(f) that performance requirements are a necessary prerequisite to the establishment of interference and sharing criteria;

(g) that preferred frequency bands for passive sensing measurements are contained in Report 693;

(h) that information related to performance requirements of passive sensors is contained in Reports 693, 694 and 850;

(j) that performance requirements for passive sensors can be stated in terms of measurement sensitivity, ΔT_e, and availability, measured at the satellite, assuming that degradation from other elements in the system will be small,

UNANIMOUSLY RECOMMENDS

1. that the frequency bands and the measurement sensitivities for passive sensing of properties of the Earth's land, oceans and atmosphere are as follows:

Frequency (GHz)	Suggested bandwidth (MHz)	Required ΔT_e (K)	Measurements
Near 1.4	100	0.1	Soil moisture, salinity
Near 2.7	60	0.1	Salinity, soil moisture
Near 5	200	0.3	Estuarine temperature
Near 6	400	0.3	Ocean temperature
Near 11	100	1.0	Rain, snow, lake ice, sea state
Near 15	200	0.2	Water vapour, rain
Near 18	200	0.2	Rain, sea state, ocean ice, water vapour
Near 21	200	0.2	Water vapour, liquid water
22.235	300	0.4	Water vapour, liquid water
Near 24	400	0.2	Water vapour, liquid water
Near 30	500	0.2	Ocean ice, water vapour, oil spills, clouds, liquid water
Near 37	1000	1.0	Rain, snow, ocean ice, water vapour
Near 55	250 (multiple) (1)	0.3	Temperature
Near 90	6000	1.0	Clouds, oil spills, ice, snow
100.49	2000	0.2	Nitrous oxide
110.80	2000	0.2	Ozone
115.27	2000	0.2	Carbon monoxide
118.70	2000	0.2	Temperature
125.61	2000	0.2	Nitrous oxide
150.74	2000	0.2	Nitrous oxide
164.38	2000	0.2	Chlorine oxide
167.20	2000	0.2	Chlorine oxide
175.86	2000	0.2	Nitrous oxide
183.31	2000	0.2	Water vapour
184.75	2000	0.2	Ozone
200.98	2000	0.2	Nitrous oxide
226.09	2000	0.2	Nitrous oxide
230.54	2000	0.2	Carbon monoxide
235.71	2000	0.2	Ozone
237.15	2000	0.2	Ozone
251.21	2000	0.2	Nitrous oxide
276.33	2000	0.2	Nitrous oxide
301.44	2000	0.2	Nitrous oxide
325.10	2000	0.2	Water vapour
345.80	2000	0.2	Carbon monoxide
364.32	2000	0.2	Ozone
380.20	2000	0.2	Water vapour

(1) Several bands, each of 250 MHz bandwidth.

2, that, in shared frequency bands, availability of passive sensor data as enumerated above shall exceed 95% of all locations in the sensor service area.

RECOMMENDATION 577-2

PREFERRED FREQUENCY BANDS FOR ACTIVE SENSING MEASUREMENTS

(Question 12/2 and Study Programme 12B/2)

(1982-1986-1990)

The CCIR,

CONSIDERING

(a) that spaceborne active microwave sensors can provide unique information on physical properties of the Earth as discussed in Report 693;

(b) that the sensing of different physical properties requires the use of different frequencies;

(c) that the spatial resolution of the measurement determines the necessary bandwidth;

(d) that simultaneous measurements at a number of frequencies may be needed to distinguish between the various properties;

(e) that sharing is feasible between some spaceborne active microwave sensors and terrestrial radars in some bands of the radiolocation service (Recommendation 516),

UNANIMOUSLY RECOMMENDS

1. that for active sensing measurements of the Earth for:

- soil moisture;
- vegetation mapping;
- snow distribution, depth and water content;
- geological mapping;
- land use mapping;
- ice boundaries, depth, type and age;
- ocean wave structure;
- ocean wind speed and direction;
- mapping of ocean circulation (currents and eddies);
- oil spills;
- geodetic mapping;
- rain rates;
- cloud height and extent;
- surface pressure,

the following frequency bands be used;

- near 1 GHz,
- near 3 GHz,
- near 5 GHz,
- near 10 GHz,
- near 14 GHz,
- near 17 GHz,
- near 35 GHz,
- near 76 GHz;

2. that bandwidths of 100 MHz should be available for active sensor applications except for altimeter measurements having spatial resolution requirements better than 50 cm;

3. that bandwidths of 600 MHz should be available for some applications with altimeters.

RECOMMENDATION 516*

FREQUENCY BANDS FOR ACTIVE SENSORS USED ON EARTH EXPLORATION AND METEOROLOGICAL SATELLITES

(Question 12/2 and Study Programme 12B/2)

(1978)

The CCIR,

CONSIDERING

(a) that, in certain frequency bands, space-borne active microwave sensors can provide unique information on physical properties of the Earth, as explained in Report 693;

(b) that space-borne active microwave sensors currently used are radars, radiating in general very short bursts of microwave energy;

(c) that existing and planned space-borne active microwave sensors have operating characteristics similar to those of terrestrial and air-borne radars;

(d) that terrestrial and air-borne radars share common frequency bands;

(e) that Report 695 examines a probable worst case example of mutual interference between some space-borne active microwave sensors and terrestrial radars;

(f) that Report 695 shows sharing to be feasible between some space-borne active microwave sensors and terrestrial radars in some bands of the Radiolocation Service,

UNANIMOUSLY RECOMMENDS

1. that it would be technically feasible for some bands of the Radiolocation Service to share with space-borne active microwave sensors.

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* This Recommendation should be brought to the attention of Study Group 8.

RECOMMENDATION 362-2

FREQUENCIES TECHNICALLY SUITABLE FOR METEOROLOGICAL SATELLITES

(Question 12/2 and Study Programme 12C/2)

(1963-1970-1982)

The CCIR,

CONSIDERING

(a) that the value of meteorological-satellite systems is well proven;

(b) that some meteorological satellites are operating in a routine manner as indicated in Report 395;

(c) that certain bands are now allocated internationally to the meteorological aids service;

(d) that certain of the frequency needs of meteorological satellites may be satisfied through the use of the meteorological aids allocations established at present,

UNANIMOUSLY RECOMMENDS

1. that bands 8, 9 and 10 are technically suitable for narrow-band and wideband meteorological data transmission;

2. that frequencies allocated to the radiolocation services in bands 10 and 11 are technically suitable for use by the precipitation detection radar and cloud detection radar on board meteorological satellites.

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SECTION 2G: RADIOASTRONOMY AND RADAR ASTRONOMY

RECOMMENDATION 314-7*

PROTECTION FOR FREQUENCIES USED FOR RADIOASTRONOMICAL MEASUREMENTS

(Question 5/2)

(1953-1956-1959-1966-1970-1974-1978-1982-1986-1990)

The CCIR,

CONSIDERING

(a) that the development of radioastronomy has already led to major technological advances, particularly in receiving techniques, and to improved knowledge of fundamental radio-noise limitations of great importance to radiocommunication, and promises further important results;

(b) that protection from interference on certain frequencies is essential to the advancement of radioastronomy and the associated measurements;

(c) that revised lists of the frequencies of the astrophysically most important spectral lines were approved by the General Assembly of the International Astronomical Union (IAU), 1988;

(d) that astronomers also study spectral lines outside bands allocated to radioastronomy, as far as spectrum usage by other services allows;

(e) that account should be taken of the Doppler shifts of the lines, resulting from the motion of the sources;

(f) that, for other types of radioastronomical observation, a certain number of frequency bands are in use, the exact positions of which in the spectrum are not of critical importance, but of which the centre frequencies should be approximately in the ratio of two to one;

(g) that propagation conditions at frequencies below about 40 MHz are such that a transmitter operating anywhere on the Earth might cause harmful interference to radioastronomy;

(h) that radioastronomers have demonstrated their ability to make useful astronomical observations from the Earth's surface at frequencies as low as 2 MHz;

(j) that the movement of the Moon produces occultations of radio sources, permitting unique radioastronomical observations of high resolution which are particularly important at metre wavelengths;

(k) that the sensitivity of radioastronomical receiving equipment, which is still steadily improving, greatly exceeds the sensitivity of communications and radar equipment;

(l) that harmful interference to radioastronomy can be caused by terrestrial transmissions reflected by the Moon, by aircraft, and possibly by artificial satellites;

(m) that some transmissions from spacecraft introduce problems of interference to radioastronomy and that these cannot be avoided by choice of site for an observatory or by local protection;

(n) that certain types of radioastronomical observation require long periods of uninterrupted recording, sometimes up to several days;

(o) that some types of high-resolution interferometric observations require simultaneous reception, at the same radio-frequency, by receiving systems located in different countries or on different continents;

(p) that some degree of protection can be achieved by appropriate frequency assignments on a national rather than an international basis;

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* This Recommendation should be brought to the attention of Study Group 1, with particular reference to Question 45/1.

(q) that the World Administrative Radio Conference, Geneva, 1979, made improved allocations for radio-astronomy, but that protection in many bands, particularly below 20 GHz, will need careful planning of other radio services;

(r) that the technical criteria concerning harmful interference, referred to in Recommendation No. 61 of the World Administrative Radio Conference, Geneva, 1979, should in respect of the radioastronomy service be those set out in Tables I and II of Report 224 for terrestrial transmitters operating outside the main beam of the radioastronomy antenna,

UNANIMOUSLY RECOMMENDS

1. that radioastronomers should be encouraged to choose sites as free as possible from interference;

2. that administrations should afford all practicable protection to the frequencies used by radioastronomers in their own and neighbouring countries;

3. that particular attention should be given to securing or maintaining adequate protection for the frequency bands listed in Tables I and II, which contain rest frequencies and Doppler-shifted frequencies of the astrophysically most important spectral lines identified by the General Assembly of the International Astronomical Union (IAU), 1988;

4. that administrations should bear in mind the technical desirability of affording protection to radio astronomy at frequencies below 10 MHz while taking CONSIDERING *(f)* and *(h)* into account;

5. that consideration be given to securing improvement in the international protection of the series of frequency bands above 10 MHz, now available to the radioastronomy service, in accordance with the Radio Regulations as amended by the World Administrative Radio Conference, Geneva, 1979;

6. that administrations, in seeking to afford protection to particular radioastronomical observations, should take all practical steps to reduce to the absolute minimum amplitude, harmonic radiations and other spurious emissions falling within the band of the frequencies to be protected for radioastronomy, particularly those emissions from aircraft, spacecraft and balloons;

7. that it is very difficult for the radioastronomy service to share frequencies with any other service in which direct line-of-sight paths from the transmitters to the observatories are involved. Above about 40 MHz sharing may be practicable with services in which the transmitters are not in direct line-of-sight from the observatories, but coordination may be necessary, particularly if the transmitters are of high power;

8. that administrations be asked to provide assistance in the coordination of experimental observations of spectral lines in bands not allocated to radioastronomy.

TABLE I – *Radio-frequency lines of the greatest importance to radioastronomy at frequencies below 275 GHz*

Substance	Rest frequency	Suggested minimum band	Notes (1)
Deuterium (DI)	327.384 MHz	327.0- 327.7 MHz	
Hydrogen (HI)	1420.406 MHz	1370.0- 1427.0 MHz	(2), (3)
Hydroxyl radical (OH)	1612.231 MHz	1606.8- 1613.8 MHz	(3), (4)
Hydroxyl radical (OH)	1665.402 MHz	1659.8- 1667.1 MHz	(4)
Hydroxyl radical (OH)	1667.359 MHz	1661.8- 1669.0 MHz	(4)
Hydroxyl radical (OH)	1720.530 MHz	1714.8- 1722.2 MHz	(3), (4)
Methyladyne (CH)	3263.794 MHz	3252.9- 3267.1 MHz	(3), (4)
Methyladyne (CH)	3335.481 MHz	3324.4- 3338.8 MHz	(3), (4)
Methyladyne (CH)	3349.193 MHz	3338.0- 3352.5 MHz	(3), (4)
Formaldehyde (H_2CO)	4829.660 MHz	4813.6- 4834.5 MHz	(3), (4)
Methanol (CH_3OH)	12.178 GHz	12.17 - 12.19 GHz	(3), (6)
Formaldehyde (H_2CO)	14.488 GHz	14.44 - 14.50 GHz	(3), (4)
Cyclopropenylidene (C_3H_2)	18.343 GHz	18.28 - 18.36 GHz	(3), (4), (6)
Water vapour (H_2O)	22.235 GHz	22.16 - 22.26 GHz	(3), (4)
Ammonia (NH_3)	23.694 GHz	23.61 - 23.71 GHz	(4)
Ammonia (NH_3)	23.723 GHz	23.64 - 23.74 GHz	(4)
Ammonia (NH_3)	23.870 GHz	23.79 - 23.89 GHz	(4)
Silicon monoxide (SiO)	42.821 GHz	42.77 - 42.86 GHz	
Silicon monoxide (SiO)	43.122 GHz	43.07 - 43.17 GHz	
Carbon monosulphide (CS)	48.991 GHz	48.94 - 49.04 GHz	
Deuterated formylium (DCO^+)	72.039 GHz	71.96 - 72.11 GHz	(3)
Silicon monoxide (SiO)	86.243 GHz	86.16 - 86.33 GHz	
Formylium ($H^{13}CO^+$)	86.754 GHz	86.66 - 86.84 GHz	
Ethynyl radical (C_2H)	87.3 GHz	87.21 - 87.39 GHz	(5)
Hydrogen cyanide (HCN)	88.632 GHz	88.34 - 88.72 GHz	(4)
Formylium (HCO^+)	89.189 GHz	88.89 - 89.28 GHz	(4)
Hydrogen isocyanide (HNC)	90.664 GHz	90.57 - 90.76 GHz	
Diazenylium (N_2H^+)	93.174 GHz	93.07 - 93.27 GHz	
Carbon monosulphide (CS)	97.981 GHz	97.65 - 98.08 GHz	(4)
Carbon monoxide ($C^{18}O$)	109.782 GHz	109.67 -109.89 GHz	
Carbon monoxide (^{13}CO)	110.201 GHz	109.83 -110.31 GHz	(4)
Carbon monoxide ($C^{17}O$)	112.359 GHz	112.25 -112.47 GHz	(6)
Carbon monoxide (CO)	115.271 GHz	114.88 -115.39 GHz	(4)
Formaldehyde ($H_2{}^{13}CO$)	137.450 GHz	137.31 -137.59 GHz	(3), (6)
Formaldehyde (H_2CO)	140.840 GHz	140.69 -140.98 GHz	
Carbon monosulphide (CS)	146.969 GHz	146.82 -147.12 GHz	
Water vapour (H_2O)	183.310 GHz	183.12 -183.50 GHz	
Carbon monoxide ($C^{18}O$)	219.560 GHz	219.34 -219.78 GHz	
Carbon monoxide (^{13}CO)	220.399 GHz	219.67 -220.62 GHz	(4)
Carbon monoxide (CO)	230.538 GHz	229.77 -230.77 GHz	(4)
Carbon monosulphide (CS)	244.953 GHz	244.72 -245.20 GHz	(6)
Hydrogen cyanide (HCN)	265.886 GHz	265.62 -266.15 GHz	
Formylium (HCO^+)	267.557 GHz	267.29 -267.83 GHz	
Hydrogen isocyanide (HNC)	271.981 GHz	271.71 -272.25 GHz	

(1) If Notes (4) or Note (2) are not listed, the band limits are the Doppler-shifted frequencies corresponding to radial velocities of ± 300 km/s (consistent with line radiation occurring in our galaxy).

(2) An extension to lower frequency of the allocation of 1400-1427 MHz is required to allow for the higher Doppler shifts for HI observed in distant galaxies.

(3) The current international allocation is not primary and/or does not meet bandwidth requirements. See the Radio Regulations for more detailed information.

(4) Because these line frequencies are also being used for observing other galaxies, the listed bandwidths include Doppler shifts corresponding to radial velocities of up to 1000 km/s. It should be noted that HI has been observed at frequencies reshifted to 500 MHz, while some lines of the most abundant molecules have been detected in galaxies with velocities up to 50 000 km/s, corresponding to a frequency reduction of up to 17%.

(5) There are six closely spaced lines associated with this molecule at this frequency. The listed band is wide enough to permit observations of all six lines.

(6) This line frequency is not mentioned in Article 8 of the Radio Regulations.

TABLE II – *Radio-frequency lines of the greatest importance to radioastronomy at frequencies between 275 and 811 GHz (not allocated in the Radio Regulations)*

Substance	Rest frequency (GHz)	Suggested minimum band (GHz)
Diazenylium (N_2H^+)	279.511	279.23-279.79
Carbon monoxide ($C^{18}O$)	329.330	329.00-329.66
Carbon monoxide (^{13}CO)	330.587	330.25-330.92
Carbon monosulphide (CS)	342.883	342.54-343.23
Carbon monoxide (CO)	345.796	345.45-346.14
Hydrogen cyanide (HCN)	354.484	354.13-354.84
Formylium (HCO^+)	356.734	356.37-357.09
Diazenylium (N_2H^+)	372.672	372.30-373.05
Water vapour (H_2O)	380.197	379.81-380.58
Carbon monoxide ($C^{18}O$)	439.088	438.64-439.53
Carbon monoxide (^{13}CO)	440.765	440.32-441.21
Carbon monoxide (CO)	461.041	460.57-461.51
Heavy water (HDO)	464.925	464.46-465.39
Carbon (CI)	492.162	491.66-492.66
Water vapour ($H_2{}^{18}O$)	547.676	547.13-548.22
Water vapour (H_2O)	556.936	556.37-557.50
Ammonia ($^{15}NH_3$)	572.113	571.54-572.69
Ammonia (NH_3)	572.498	571.92-573.07
Hydrochloric acid (HCl)	625.918	625.29-626.54
Carbon monoxide (CO)	691.473	690.78-692.17
Hydrogen cyanide (HCN)	797.433	796.64-798.23
Formylium (HCO^+)	802.653	801.85-803.85
Carbon monoxide (CO)	806.652	805.85-807.46
Carbon (CI)	809.350	808.54-810.16

RECOMMENDATION 611-1 *

PROTECTION OF THE RADIOASTRONOMY SERVICE FROM SPURIOUS EMISSIONS

(Question 5/2 and Study Programme 5A/2)

(1986-1990)

The CCIR,

CONSIDERING

(a) that radioastronomy continues to be in the forefront of the expansion of scientific knowledge;

(b) that the radioastronomy service requires frequency bands free of harmful interference in order that astronomical observations can be made;

(c) that the growing use of the radio spectrum, particularly in space, increases the possibility of harmful interference to radioastronomy from spurious emissions;

(d) that Appendix 8 to the Radio Regulations establishes the maximum permitted levels of spurious emissions from transmitters operating at frequencies below 17.7 GHz;

(e) that stations in the space services operating at frequencies above 960 MHz are excluded from the application of Appendix 8 to the Radio Regulations;

(f) that radioastronomy observations are conducted in frequency bands up to, and above, 275 GHz;

(g) that the technical criteria concerning harmful interference, referred to in Recommendation No. 61 of the WARC-79, should, in respect of the radioastronomy service, be those set out in Tables I and II of Report 224 for transmitters operating outside the main beam of the radioastronomy antenna;

(h) that the technical criteria for the special case of harmful interference due to spurious emissions from transmitters in geostationary space stations should, in respect of the radioastronomy service, be those set out in Reports 224 and 697 enabling radioastronomy observations to be made at 5° or more from the geostationary-satellite orbit;

(j) that, as evidenced in Report 807, progress has been made in meeting the requirements of the radioastronomy service without detrimental effects on other services;

(k) that there are continuing improvements in antenna design,

UNANIMOUSLY RECOMMENDS

1. that the radioastronomy service continues to place observatories in locations which have good natural protection from harmful interference;

2. that the radioastronomy service not rely on protection from harmful interference due to the spurious emissions of geostationary satellites when observing within 5° of the geostationary-satellite orbit;

3. that the radioastronomy service should make all practicable efforts to minimize the side-lobe gains of radioastronomy antennas;

4. that, in bringing stations into operation in frequency bands not covered by the provisions of Appendix 8 to the Radio Regulations, administrations should take into account, to the maximum extent practicable, the special risk of interference to radioastronomy observations due to spurious emissions from high-powered terrestrial stations or from space stations;

5. that, for the special case of geostationary space stations, administrations should take into account, to the maximum extent practicable, the objective of the radioastronomy service to be free of harmful interference from spurious emissions when observing at 5° or more from the geostationary-satellite orbit.

* This Recommendation should be brought to the attention of Study Groups 1, 4, 8, 9, 10 and 11.

RECOMMENDATION 517-1 *

PROTECTION OF THE RADIOASTRONOMY SERVICE FROM TRANSMITTERS IN ADJACENT BANDS

(1978-1982)

The CCIR,

CONSIDERING

(a) the value of the scientific results achieved by the radioastronomy service through the exploration of the Universe;

(b) the need for interference-free bands at intervals throughout the radio spectrum in order that radio-astronomy measurements can be made;

(c) the levels of interference that the CCIR consider to be harmful to the radioastronomy service, as given in Report 224;

(d) the desire on the part of both active and passive users of the radio-frequency spectrum to operate in harmony without mutual interference as evidenced by the provisions of Article 6, Nos. 339 to 343 of the Radio Regulations;

(e) that No. 344 of the Radio Regulations in many cases does not unambiguously provide needed protection for radioastronomy from transmitters operating in frequency bands adjacent to a band allocated to the radioastronomy service;

(f) the difficulties currently being experienced by radio services in the design and utilization of transmitters to operate in frequency bands adjacent to a band allocated to the radioastronomy service, in such a manner as to afford adequate protection from harmful interference to the radioastronomy service;

(g) the possible future increase in the level of usage of frequency bands adjacent to bands allocated to the radioastronomy service, particularly by airborne and satellite transmitters;

(h) that it is incumbent on both active and passive radio services to find means to minimize harmful interference, acting both separately and in cooperation with each other, with due consideration for the efficient use of the radio-frequency spectrum,

UNANIMOUSLY RECOMMENDS

1. that all practical, technical means, for example, the use of filters, be adopted both in radioastronomy receivers and in adjacent band transmitters to the maximum practicable extent, in order to reduce interference to the radioastronomy service;

2. that when frequencies are assigned to a station in a service operating in a band adjacent to one allocated on a primary basis to radioastronomy, attempts should be made to limit the edge of the necessary band adjacent to the radioastronomy band, so that the power radiated within this band should produce no harmful interference to a station of that service;

3. that when future frequency assignments are made by administrations in bands adjacent to those allocated to radioastronomy, on an exclusive or primary basis, account should be taken, to the maximum extent practicable, of the special risk of interference to radioastronomy observations from space-to-Earth and airborne transmissions, within the adjacent bands;

4. that taking into account § 1, 2 and 3 above, practical solutions to the band-edge interference problem be sought by administrations individually and if necessary in cooperation, and that proposals for solutions to the problem be considered at the next competent World Administrative Radio Conference.

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* This Recommendation should be brought to the attention of Study Groups 4, 7, 8, 9, 10 and 11.

RECOMMENDATION 479-3 *

PROTECTION OF FREQUENCIES FOR RADIOASTRONOMICAL MEASUREMENTS IN THE SHIELDED ZONE OF THE MOON

(Question 7/2)

(1974-1978-1982-1990)

The CCIR,

CONSIDERING

(a) that Annex I ** contains a discussion of the shielded zone of the Moon, and preliminary guidelines on the use of the frequency spectrum in this zone;

(b) that radioastronomical discoveries resulting from observations from spacecraft above the atmosphere of the Earth will reveal unexpected new astronomical phenomena;

(c) that, in addition to the establishment of line-of-sight communication links for scientific and other purposes between the Earth and spacecraft, it may be necessary to establish links between stations on the far side of the Moon and other stations on or visible from the Earth;

(d) that Article 29, Nos. 2632-2635 of the Radio Regulations recognizes the necessity of maintaining the shielded zone of the Moon as an area of great potential for observations by the radioastronomy service and by passive space research and consequently as free as possible from transmissions;

(e) that earth satellites with high apogees, deep-space probes and transmitters located on the Moon may each illuminate the shielded zone,

UNANIMOUSLY RECOMMENDS

1. that in planning the use of the radio spectrum, both nationally and internationally, account be taken of the need to provide for radioastronomy observations in the shielded zone of the Moon;

2. that, in taking account of such a need, special attention should be given to those frequency bands in which observations are difficult or impossible from the surface of the Earth;

3. that the frequency spectrum should be used in the shielded zone of the Moon in keeping with the preliminary guidelines contained in Annex I;

4. that in the frequency bands which would be considered for joint use by active and passive space stations in the shielded zone of the Moon, radioastronomy observations should be protected from harmful interference. To this end appropriate discussions between concerned administrations may be conducted.

ANNEX I

THE PROTECTION OF RADIOASTRONOMY OBSERVATIONS IN THE SHIELDED ZONE OF THE MOON ***

The electromagnetic spectrum is now so heavily used on Earth that much of its potential value for passive scientific research has already been seriously affected. Because of the general increase in radiocommunications, especially involving earth satellites, spacecraft, and deep-space probes, it is important that frequency allocations by the International Telecommunication Union be coordinated to minimize interference with radioastronomy. In particular, since the far side of the Moon is the remaining accessible place where radio observations of the Universe will be possible without interference over the whole radio spectrum; it will be necessary to allocate frequencies for active use by deep-space probes, lunar satellites, scientific instrument packages and research stations on the lunar surface in such a way, that interference with such passive observations is avoided.

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* This Recommendation is brought to the attention of Study Groups 1 and 5.

** Annex I contains text from Report 539 which is hereby cancelled.

*** Propagation aspects of this subject are discussed in Report 336, of Study Group 5.

Part of the Moon's surface is always protected from interfering signals generated on and near the Earth because the Moon always presents nearly the same side towards the Earth. It has a period of rotation about its axis equal to its period of revolution around the Earth, but because its orbit is slightly elliptical and inclined, observers on Earth can see somewhat more than half the surface of the Moon. If, in addition, the Moon is viewed from an earth satellite in an orbit of 100 000 km radius, another small fraction is seen. The remaining invisible portion of the Moon's surface is that which lies more than 23.2° beyond the mean limb of the Moon as seen from the centre of the Earth. The shielded zone of the Moon consists of the shielded area of the Moon's surface together with an adjacent volume which is shielded from interference originating within a distance of 100 000 km from the centre of the Earth (Article 29, No. 2632.1 of the Radio Regulations).

It is important that low-frequency radioastronomical studies be shielded from interfering signals from the Earth and satellites (such as very low frequency topside ionosonde experiments), since such observations are difficult to perform on Earth below 40 MHz, and particularly below 10 MHz, due to ionospheric opacity and inhomogeneities. These low-frequency studies are capable of providing important data on solar activity, cosmic rays and magnetic fields in our galaxy, and on the low frequency spectra of quasars and pulsars.

At frequencies above 20 GHz, radioastronomy observations made from the Earth's surface are hampered by atmospheric opacity due to strong transitions of H_2O and O_2. Although observations are successfully carried out in the atmospheric windows, some important observations of galactic and intergalactic objects and of complex and interesting interstellar molecules can only be made in the absence of an atmosphere, and the absence of interference of these transition frequencies is of great importance in the shielded zone of the Moon.

The shielded zone of the Moon is expected to be free from terrestrial interference over the whole frequency spectrum. It is a unique site for scientific observations. As it is expected that radioastronomical and other scientific experiments will soon be carried out in this zone, it is essential to regulate the activities of the radio services whose facilities may illuminate it. Account must be taken of the requirements of Earth satellites, deep space probes and transmitters located in the shielded zone of the Moon, on the understanding, however, that it is desirable to maintain the shielded zone of the Moon as a zone free from radio interference and hence of great value for passive observations.

The use of the frequency spectrum by services with facilities which are located in the shielded zone of the Moon or which illuminate it could be based on the following preliminary set of guidelines, which will need to be reviewed as additional information is received.

The entire radio frequency spectrum in the shielded zone of the Moon is designated as available for passive users (the Radioastronomy Service and other passive users as defined in the Radio Regulations), with the following exceptions:

- Frequency bands currently available and allocated in the future to the Space Research Service, and those frequency bands in the Space Operation Service, the Earth Exploration-Satellite Service and the Radiodetermination-Satellite Service, that are required to support space research;

- Frequency bands currently available or allocated in the future for radiocommunication and for space research transmissions within the lunar shielded zone.

The proposed guidelines do not impose any restriction on existing or future terrestrial radio services or on existing or future space radio services, the transmitters of which are switched on at a distance of less than 100 000 km from the centre of the Earth.

Under the proposed guidelines, existing or future space radio services for which transmitters are switched on at a distance of more than 100 000 km from the Earth and which operate in accordance with the Radio Regulations should coordinate their activities with the Radio Astronomy Service. It is essential that provisions governing compatibility between the Radio Astronomy Service and other services, based on the technical features of the services, be specified by a decision adopted by an ITU Administrative Conference.

[redacted]

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